CELLPHONES ON MARS? LEVERAGING WIDEBAND CELLULAR TECHNOLOGY FOR A MARS COMMUNICATIONS INFRASTRUCTURE. J. T. Adams[1] and J. P. Lux[2], [1]Jet Propulsion Laboratory, 4800 Oak Grove Road, Pasadena CA 91109, Jon.T.Adams@jpl.nasa.gov, [2]Jet Propulsion Laboratory, 4800 Oak Grove Road, Pasadena CA 91109, James.P.Lux@jpl.nasa.gov.

Introduction: Future planetary exploration will require a wireless communications infrastructure which will provide the means for telecommand and telemetry, but also position finding and navigation. The user terminals are quite diverse in their requirements. Such terminals must be low power, but also adaptable to many roles.

The cellular telephone industry faces many of the same problems. There is an increasing diversity of coexistent networks, using different modulation formats and spectrum reuse techniques (FDMA, TDMA, CDMA). Commercial component providers have responded to this need by developing software DSP based radios that can switch from mode to mode as required. Battery life is always critical, and manufacturers have responded with low power integrated circuits to perform the various analog and digital functions required

Longevity of design: Spacecraft are developed on a much longer time scale (years) compared to commercial products (months, or even weeks). This often creates problems with designs that rely on state of the art components and architectures, because by the time the spacecraft is ready for launch, the parts being used are several generations obsolete. Finding engineers to work on the system is difficult, as well, particularly in the case of junior level engineers. However, while the actual parts used in cellular telephones will continue to advance, the architectures and modulations tend to have longer lifetimes. AMPS (the current "analog cell phone") is a design dating from the 1970's and is still being used. It is supported by modern test equipment, and engineers are available at all skill levels who are familiar with it.

Significant differences between terrestrial cellular systems and Mars infrastructure: Naturally, we cannot expect to simply take a consumer cell phone and fly it to Mars. Not only are there differences in the environment (radiation, temperature) and desired reliability information, but the propagation path is quite different. Fortunately, the adaptability of modern chip sets and architectures plays in our favor. The software radio concept, allowing multi-mode phones and fast "time to market" in the consumer area, also allows the flexibility to modify the system parameters for the different propagation environment.

Some of these differences are the much larger range in the Mars Infrastructure, significant doppler shift, and the requirement for precision navigation.

Differences in mobile/base range: Expected mobile to orbiter ranges of 400- 1500 km are some 10-30 times the mobile/base distances typical of terrestrial cellular systems. The orbiter must have a much higher gain antenna than the typical cellular base station. A orbiter gain of 40 dBi, compared to the cellular gain of 12 dBi. This favors a higher frequency than the current UHF, because gains of this magnitude would require antenna apertures of ten meters or more. Of great interest in the cellular industry [1] is the development of adaptive array antennas, which simultaneously synthesize multiple narrow beams with relatively high gain.

For the mobile units, the ranges at which we typically operate would be somewhat greater than with commercial cellular systems, requiring a larger EIRP. This can be achieved either with greater transmitter power, retaining the basically omnidirectional antenna, or by a novel scheme involving switching between several fixed moderate gain antennas, based upon either diversity power detection, or by calculation from stored ephemeris and position data.

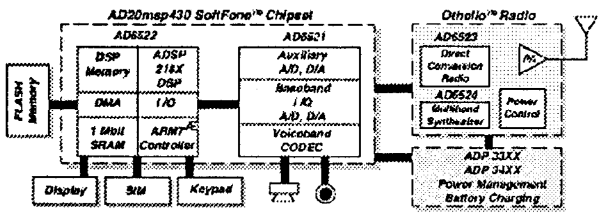
Doppler: The doppler shift on current UHF frequencies used for the lander/orbiter links is on the order of 10 kHz, and is much larger than the typical doppler for a cellular telephone application. Proposed wideband cellular systems must handle large frequency offsets due to inexpensive frequency references in the phones. The primary difference is in the frequency tracking loops, which will need different parameters to track the rapidly (in comparison to cellular systems) varying frequency offset. Fortunately, these tracking loops are implemented either as discrete RC filters or as software, either of which is amenable to adaptation for space use.

Navigation. Navigation (position finding) for the mobile units is an essential aspect of a Mars infrastructure. Cellular telephone systems have traditionally not provided this function, however, recent regulatory requirements to provide 100 meter accuracy position finding for 911 emergency calls have prompted the development of this capability. The high dynamic code tracking algorithms used for GPS, another

CDMA system, might be useful, inasmuch as cellular phones aren't usually moving at 4 km/second.

What's available today (and tomorrow):

As an example of present day technology that is directly applicable to the Mars Infrastructure, consider a set of components available from Analog Devices [3] supporting the GSM and GPDS needs. A pair of chips provides a direct conversion transceiver and synthesizer for the 900MHz and 1600MHz bands. Another pair provides the signal conversion and digital signal processing functions, as well as a microcontroller. The entire set, along with all necessary discrete components occupies less than 20 square centimeters on a single sided PC board and has a standby power consumption of less than 3 mW.



Analog Devices is only one manufacturer among many in this competitive field. The longevity issues described above means that even though the chips may change, the basic processing will remain the same, the test equipment will remain the same, and so forth.

This chipset really only provides for "voice bandwidth" services (in the 8 kbps range). For the future, the demand for wireless broadband services, ranging to hundreds of kbits/second, will be met by so-called Wideband-CDMA (or 3G). Chipsets are already being announced to support this new standard.

References: [1] Winters, J.H. (1998) *IEEE Pers. Comm. 1*, 23-27. [2] Rappaport, T.S., et.al (1996) *IEEE Comm. Mag. 34*, 10, 33-41. [3] Analog Devices (2000), http://www.analog.com/